

# Advanced Manufacturing Technologies (AMT): Additive Manufactured Hot Fire Planning and Testing in GRC Cell 32

Completed Technology Project (2013 - 2014)



## Project Introduction

The objective of this project is to hot fire test an additively manufactured thrust chamber assembly TCA (injector and thrust chamber). GRC will install the additively manufactured Inconel 625 injector, two additively manufactured (SLM) water cooled Cu-Cr thrust chamber barrels and one additively manufactured (SLM) water cooled Cu-Cr thrust chamber nozzle on the test stand in Cell 32 and perform hot fire testing of the integrated TCA.

GRC and AR have identified the following roles and responsibilities necessary to accomplish the hot fire objective of this task. AR will be responsible for delivering to GRC the additively manufactured thrust chamber components and injector, give input required for test plan documentation, participate in the test readiness review and give engineering support for hot fire testing. GRC will be responsible for preparing Cell 32 for testing, manufacturing all test support hardware, generating test plan documentation, conducting a test readiness review, conducting all hot fire operations and generating the final report.

AR will use SLM to manufacture all of the thrust chamber components necessary to perform this task. The two water cooled thrust chamber barrels and one water cooled nozzle will be constructed from Cu-Cr which is an alloy of interest for several engines in the AR product line. Following fabrication and post processing AR will conduct pretest inspections on the thrust chamber components to verify the builds. The Inconel 625 injector that will be used in this investigation is the same injector that was used in the MIP. AR has already conducted post-test inspections on this component to verify that it can be used in this work. During the course of the MIP test campaign, AR working with GRC, identified several propellant feed system modifications necessary to be made to Cell 32. The modifications entail altering the feed system and main valve placement to facilitate easier engine operation. GRC facilities personnel have already coordinated with AR personnel to select components that can easily be integrated into the current test set-up in order to streamline the modification process. To support hot fire testing GRC will fabricate several igniters and one heat sink copper thrust chamber. The design work for these components was completed under the MIP and drawings are already available. The heat sink thrust chamber will be used in early hot fire tests to verify that Cell 32 feed system modifications had the desired effect on engine operation. This will minimize risk to the AR Cu-Cr thrust chamber components and also allows additional instrumentation to be integrated into the test set-up. Data from this additional instrumentation will also be used to better understand the performance of the thrust chamber assembly after the heat sink hardware has been replaced by the water cooled SLM components.

To prepare for hot fire testing GRC, with AR input, will generate a test requirements document (TRD) to capture all of facility and test requirements necessary to ensure successful completion of the hot fire objective of this task. This document will contain a preliminary test matrix that outlines plans and the number of tests required to increase hot fire test duration from short



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ignition tests (~ 0.5 seconds) to longer duration (~30) second tests with minimal hardware risk. The longer duration tests should allow the TCA to achieve thermal equilibrium and allow preliminary insight into the effect, if any, that longer duration testing has on SLM fabricated TCA components. AR will be a signatory on the document to capture concurrence with the GRC test approach. The information in the TRD will be used as a basis for a test readiness review that will be conducted to allow GRC and AR management to review the test plans and give feedback before the team proceeds to hot fire testing.

Although GRC will be responsible for all hot fire testing operations, AR will provide on-site engineering test support during the course of hot fire testing. The on-site presence will allow GRC test engineers to coordinate with AR personnel to quickly review any data anomalies and make real time revisions to the test matrix should they be required. This approach was adopted during the MIP testing and allowed a significant amount of testing to be accomplished in a relatively short period of time thereby minimizing the cost of test operations. Following the completion of testing GRC will generate a final report summarizing the work accomplished during objective one of this task and deliver it to GCDP management.

## Anticipated Benefits

Cost Savings •AR demonstrated 70% cost savings for the injector Direct infusion •NASA SMD and DOD use EELVs to launch payloads to orbit •RL-10 is the upper stage engine for the Atlas V and Delta IV •RL10 is the baseline engine for SLS ICPS and SLS 100t dual use upper stage NASA strengthens the partnership with AR and extends NASA influence on RL10 TRL enhancement (3 to 5) Increases NASA knowledge base of RL10 and cultivates experience that can be passed on as RL10 continues to evolve

## Organizational Responsibility

### Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

### Lead Center / Facility:

Glenn Research Center (GRC)

### Responsible Program:

Game Changing Development

## Project Management

### Program Director:

Mary J Werkheiser

### Program Manager:

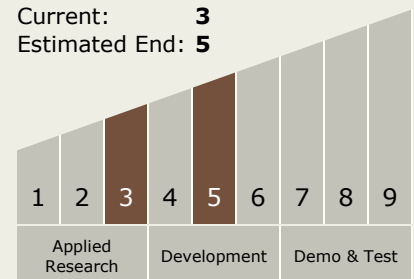
Gary F Meyering

### Principal Investigator:

Lanetra C Tate

## Technology Maturity (TRL)

Start: 3  
Current: 3  
Estimated End: 5

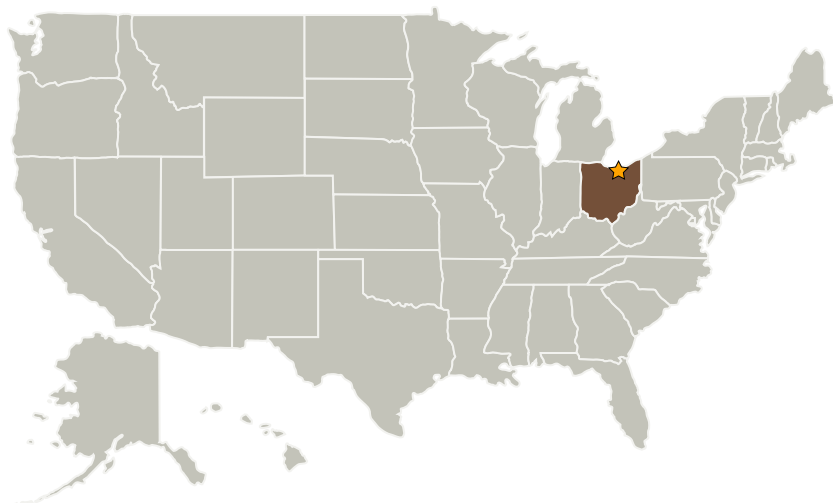


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## Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Glenn Research Center(GRC)	Lead Organization	NASA Center	Cleveland, Ohio

Co-Funding Partners	Type	Location
Aerojet Rocketdyne Holdings, Inc.	Industry	El Segundo, California

Primary U.S. Work Locations
Ohio

## Stories

Success - Hot Fire Tests

(<https://techport.nasa.gov/file/21836>)

## Technology Areas

### Primary:

- TX13 Ground, Test, and Surface Systems
  - └ TX13.1 Infrastructure Optimization
    - └ TX13.1.4 Propellant Production, Storage and Transfer